CITY OF **PORT ANGELES**

WASHINGTON, U. S. A.

City Manager's Office

August 11, 2006

Pete Kmet
Department of Ecology
Toxics Cleanup Program
P.O. 47600
Olympia, WA 98504-7600

TRANSMISSION VIA E-MAIL
AUGUST 11, 2006

Re: Department of Ecology proposed amendment to Model Toxics Control Act Cleanup Regulation, Chapter 173-340 WAC, to change the policies and procedures for establishing cleanup levels for dioxins/furans, PAHs and PCBs.

Dear Mr. Kmet:

Attached to this letter is a report prepared at the request of the City of Port Angeles. The City has hired an independent firm to evaluate the potential effect of the proposed changes to the Model Toxics Control Act as it relates to the cleanup levels for dioxins and mixtures. This is the report prepared for the City of Port Angeles. The City staff has reviewed this, we approve it, and we are submitting this to you as the City's comments with regard to that proposed rule making.

If you have any questions that you would like to discuss please feel free to contact me.

Very truly yours,

Mark E. Madsen

Mark E. Madsen
City Manager

WEB:rf

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Exponent®

# Technical Memorandum

# Evaluation of the Effect of the Model Toxics Control Act Draft Rule Amendment for Dioxins in Soil

Prepared for

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Port Angeles, Washington

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August 2006

Doc. no.  BE03079.001 0101 0806 JT02

# Evaluation of the Effect of the Model Toxics Control Act Draft Rule Amendment for Dioxins in Soil

This memorandum evaluates cleanup level revisions for dioxin and dioxin-like compounds (a.k.a. dioxins) that would result from the Washington State Department of Ecology's (Ecology's) July 2006 Draft Rule Amendment for their Model Toxics Control Act (MTCA). The focus of this evaluation is the health protectiveness of the Method B cleanup level for unrestricted land use and the risk assessment methodology that forms the basis of this cleanup level.[1] In particular, this memorandum evaluates whether the revised cleanup level is necessary for the protection of health.

The following sections review the overall basis of health risk assessment for dioxins, present the change in the dioxin cleanup level that would result from the draft rule amendment, and discuss the scientific evidence on the health protectiveness of this level. Perspective is also provided on national cleanup levels set by the federal government and on how the revised cleanup level would compare to background levels to which much of the population is exposed.

This evaluation finds that the proposed Method B cleanup level is unnecessarily stringent. In addition, because this proposed cleanup level is likely to be below background concentrations in many areas in the state, implementing this stringent cleanup level would be impractical.

## Background on Dioxin Risk Assessment

Risk assessment is a regulatory tool that provides information about hypothetical risks under assumed exposure conditions. Because risk assessment is conducted to protect public health even for the maximum reasonably exposed individual, it is likely to overestimate risks for many individuals.

Dioxin is the common term for polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDDs/Fs), a group of two structurally similar families of chlorinated chemicals that differ in their number and position of chlorine atoms in each congener. Dioxin congeners are ubiquitous in the environment. Industrial sources of PCDDs/Fs include incineration of municipal and certain industrial wastes, chlorination processes used in pulp and paper manufacturing and other water treatment systems, and the production and use of certain chlorinated pesticides. Residential sources are also common, such as wood and trash burning, fossil fuel combustion emissions, and other combustion sources. PCDDs/Fs are typically present in the environment as a mixture of many individual compounds. One member of a group of PCDD/F congeners, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) is the most extensively studied and is thought to be the most toxic compound within this chemical class. As a result, the toxicity and

[1] The less-used Method C cleanup level for industrial land use has a risk assessment basis similar to the Method B level, but is ten times higher because a ten times higher risk goal is applied. Thus, comments regarding the risk assessment basis of the Method B cleanup level are also applicable to the Method C cleanup level.

other data for this chemical frequently provide the foundation for assessing the hazard associated with related congeners that are less well studied. In particular, some of these congeners, especially those with chlorine at the 2, 3, 7, and 8 positions, have shown effects similar to those of 2,3,7,8-TCDD and thus are included in dioxin risk assessments.

The U.S. Environmental Protection Agency (EPA) has classified 2,3,7,8-TCDD as a probable human carcinogen (i.e., Group B2 carcinogen) based on inadequate data in human populations, but sufficient evidence in laboratory animals. Although numerous epidemiological studies have been undertaken to assess the potential carcinogenicity of 2,3,7,8-TCDD and related compounds in humans, such studies have not shown strong evidence of carcinogenicity in humans and generally suffer from several limitations. In particular, accurate exposure data typically have been lacking and the studied individuals have frequently had potentially confounding exposures to other chemicals. The toxicity of dioxins has been shown to vary greatly among animal species. Humans do not appear to be the most sensitive, but use of animal data including the most sensitive species is part of health-protective regulatory policy.

EPA is in the midst of re-evaluating the toxicity of PCDD/Fs, but most risk assessments of dioxin compounds in soil are still evaluated based on a prior carcinogenic slope factor for ingestion or inhalation of 2,3,7,8-TCDD of $1.5 \times 10^5$ $(\text{mg/kg-day})^{-1}$ (U.S. EPA 1985). This value was derived on the basis of data indicating an increased incidence of tumors of the liver, lung, and nasal turbinates observed in female rats in a chronic feeding study conducted by Kociba et al. (1978). This toxicity value was derived through application of doses much higher than those experienced by people in the workplace or the environment, and assumes that there is no threshold below which a carcinogenic risk for PCDD/Fs is zero.

EPA has not developed quantitative toxicity factors for any other specific PCDD/F congeners because of the limited toxicological information available for these compounds.[2] Instead, EPA applies a toxicity equivalence factor (TEF) approach for quantitatively estimating the toxicity of 16 other congeners (with chlorine substitutions in the 2,3,7,8 positions) that is based on their likely toxicity relative to that of 2,3,7,8-TCDD (van den Berg et al. 1998). These TEFs were recently re-evaluated by a World Health Organization (WHO) expert panel (van den Berg et al. 2006). The TEF approach was developed under the assumption that dioxin-like chemicals exert their carcinogenic effect via a similar mechanism of action in the body. In the TEF approach, 2,3,7,8-TCDD is assigned a weighting factor, or TEF, of 1. The other 16 PCDD/F congeners are assigned weighting factors based on their toxicity relative to 2,3,7,8-TCDD. To apply the TEF approach to a PCDD/F mixture, the concentrations of the 17 congeners (including 2,3,7,8-TCDD) are multiplied by their respective TEFs and are then summed to yield the equivalent concentration of 2,3,7,8-TCDD. This sum is termed the 2,3,7,8-TCDD toxic equivalent (TEQ). Individual congeners differ greatly in toxicity (e.g., TEFs range from 1 to 0.00001 times the toxicity of 2,3,7,8-TCDD). There is considerable uncertainty related to the

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[2] EPA has developed a cancer slope factor for use in estimating risks associated with ingestion and inhalation exposures to mixtures of hexachlorodibenzo-*p*-dioxins (U.S. EPA 2006). Risk assessments for PCDDs/Fs, however, typically use the TEF approach to estimate the carcinogenic risks associated with these compounds. The TEF approach yields more conservative risk estimates.

TEFs used in these calculations as noted by Ecology in their documentation and as discussed further below.

## Impact of Draft MTCA Rule Amendment for Dioxins

In response to ambiguity in the MTCA rule, the draft rule amendment clarifies Ecology's policy on how TEF values should be used in establishing MTCA Method B and Method C cleanup levels. Under Method B (unrestricted land use), the total site risk for carcinogenic substances cannot exceed 1 in 100,000 ($10^{-5}$) and the cancer risk for individual substances cannot exceed 1 in a million ($10^{-6}$). Under Method C (industrial land use), these target risk levels are ten times higher. MTCA allows the use of TEF values to assess the potential cancer risk and develop cleanup levels for dioxin and furan mixtures. The draft rule amendment specifies that mixtures of dioxin and furan congeners, however, be considered a single hazardous substance rather than multiple hazardous substances in determining compliance with MTCA cleanup levels and remediation levels. Accordingly, a cancer risk of $10^{-6}$ would be applied to the TEQ for the mixture (sum of the 17 individual TEQs) under Method B and a risk of $10^{-5}$ will be applied under Method C. The allowable risk level and associated cleanup level for dioxin and furan mixtures is thus ten times lower than the risk for other mixtures of hazardous substances.

In support of their draft rule amendment, Ecology notes that dioxin and furan congeners, although chemically distinct, have similar mechanisms of action and consequently behave as similar chemicals in the body. Ecology also cites the widespread practice by other environmental agencies of summing TEF concentrations in assessing risks and cleanup levels. Nevertheless, not all agencies, including the federal government, require that the sum of TEF concentrations meet a stringent total risk of no more than $10^{-6}$. Nevertheless, Ecology should consider whether more stringent cleanup levels are necessary to protect health and or are even feasible.

## Necessity of the Draft Rule Amendment for Dioxins to Protect Health

Many conservative assumptions that drive estimated risks upward and cleanup levels lower are inherent in risk assessment of dioxins. As a result, a stringent Method B cleanup level using a lower risk goal of $10^{-6}$ for the TEQ sum of dioxin and furan mixtures is unnecessary and is likely to result in a target concentration lower than background levels in many developed areas.

Current scientific evidence indicates that the cancer risk associated with lower dioxin TEQ doses in the extrapolated low risk range (e.g., associated with a $10^{-4}$ risk and lower) is likely negligible. Specifically, although the EPA cancer slope factor for assessing health risks of dioxins assumes a linear dose-response relationship at low doses, current science (reviewed by NAS 2006) indicates that the relationship at low doses is likely non-linear, and that risks are actually lower than predicted based on a linear relationship. The recent National Academy of Sciences (NAS) expert panel (NAS 2006) that reviewed the EPA dioxin reassessment noted that a non-linear model was more supported by the scientific evidence than the existing linear approach.

Evidence cited by NAS (2006) as supporting a lower risk at low doses or even a practical threshold for risk from dioxins includes its mechanism of action, lack of direct genotoxicity, and results from animal bioassay studies. The mechanism of toxic action at high doses leading to cancer is likely not applicable at low doses. For example, because liver toxicity is a likely precursor to liver cancer, exposures below levels causing liver toxicity would not be expected to lead to cancer. Dioxins are not direct genotoxic carcinogens (e.g., substances that cause point mutations on DNA leading to cancer). Rather, they cause toxicity and potential tumor formation by means that require sufficiently high concentration in the body to bind with receptors and cause activation or to result in accumulation of a sufficient amount of stress or damage to overwhelm the body's defenses. Such mechanisms would have little, if any, contribution to cancer risk at low doses. As a result, the current cancer slope factor is very protective for estimating risks and cleanup levels. Moreover, because the dose-response relationship is likely sublinear, TEQ mixture concentrations associated with a $10^{-5}$ risk are already within the low dose range in which toxicity and cancer risks are negligible. Lowering of concentrations to meet a $10^{-6}$ risk level would have no actual benefit for reduced cancer risk.

The cancer slope factor for 2,3,7,8-TCDD (and applied in the TEF approach to the other 16 related congeners) is also based on exposure to dioxins in well-absorbed media such as food or corn oil. As noted by the WHO expert panel (van den Berg et al. 2006), chemical differences among dioxin-like compounds greatly affect lipid and water solubility, which in turn affects their environmental transport and fate and gastrointestinal bioavailability.[3] A recent paper by Warmerdam et al. (2006) reports on the results of simulated gastrointestinal bioaccessibility measurements for different congeners of dioxins and furans in soil at an industrial site (Attachment 1). Bioaccessibility for most congeners ranged from approximately 10 to 25 percent, with two congeners (1,2,3,7,8,9-HxCDF and 2,3,4,6,7,8-HxCDF) showing much higher bioaccessibility of approximately 55 and 48 percent, respectively.

Thus, adding all TEQ concentrations without correction for differences in bioavailability, for example, is scientifically inaccurate because it assumes equal exposure to all congeners despite their great differences in bioavailability and actual absorbed dose in the body. For this reason, the WHO expert panel (van den Berg et al. 2006) recommendations indicate that the use of separate risk assessment equations for each congener would be appropriate. These differences among compounds reinforce that dioxins should be evaluated as a mixture of chemicals that have different environmental and biological behavior rather than as a single substance.

Adding TEF concentrations together also compounds the health protective bias in each TEF. The individual TEFs for the congeners are based on upper percentile estimates (e.g., above the 75th, 90th percentile) of toxicity from the existing studies (van den Berg et al. 2006; Haws et al. 2006). As a result, as noted by the WHO expert panel (van den Berg et al. 2006), probabilistic modeling approaches (e.g., Haws et al. 2006), which estimate TEFs for individual congeners

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[3] Comments by Dr. Jeff Louch (National Council for Air and Stream Improvement, Inc.) provide additional details on studies that have reported differences in bioavailability of congeners.

based on the full range of the data from different studies, are able to incorporate the effect of potential uncertainties in TEFs with less bias.

Additional work not reviewed by the NAS panel includes recent National Toxicology Program cancer bioassays for 2,3,7,8-TCDD and 2,3,4,7,8-pentachlorodibenzofuran (4-PeCDF) (reviewed by Budinsky et al. 2006). These studies provide better pharmacokinetic data than was previously available. Using these data, Budinsky et al. (2006) estimated that the TEF for 4-PeCDF of 0.5 identified in van den Berg et al. (1998) is likely overestimated and that instead the data support an administered dose TEF no greater than 0.25 and a TEF in the 0.05–0.1 range "for internal dose metrics such as lifetime average liver concentration or body burden."

## Perspective from National Cleanup Levels

National soil cleanup levels for dioxins as identified by EPA and dioxin soil screening guidelines identified by the Agency for Toxic Substances and Disease Control (ATSDR) are considerably higher than the cleanup level for dioxins that would result from the draft rule amendment. Although Ecology correctly notes that ATSDR and EPA both use a total TEQ approach as the basis for comparing site-specific data to cleanup levels, the target cleanup levels identified by the references cited are much higher than the values that would result from the proposed Ecology methods.

Specifically, ATSDR provides a screening level of 50 ng/kg (ppt) TEQ as the starting point in considering whether some evaluation is needed for residential sites in its publication titled *Dioxin and Dioxin-like Compounds in Soil: Part I. ATSDR Interim Policy Guideline* and *Part II: Technical Support Document for ATSDR Interim Policy Guideline* (ATSDR 1997). In their evaluation, ATSDR considered all toxicological data available at that time and concluded that, for residential soils, concentrations up to 50 ng/kg TEQ would be protective for all potential adverse effects. ATSDR also identified an "evaluation level" for PCDD/Fs in the range of 50 ng/kg TEQ to 1,000 ng/kg TEQ, where ATSDR recommends that site-specific factors such as bioavailability, climate, community concerns, and other factors be considered in determining whether any additional evaluation or further protective measures are needed. Levels above 1,000 ng/kg TEQ were identified by ATSDR as an "action level," above which potential public health measures should be considered (Table 1).

**Table 1. Comparison of MTCA draft TEQ cleanup levels with screening values and cleanup values for TEQs in soil**

| Source | PCDDs/Fs TEQ (ng/kg) |
|---|---|
| MTCA draft Method B cleanup level | 6.67 |
| MTCA draft Method C cleanup level | 66.7 |
| ATSDR screening level (ATSDR 1997) | Less than or equal to 50 |
| ATSDR evaluation levels (ATSDR 1997) | Greater than 50 but less than 1,000 |
| ATSDR action level (ATSDR 1997) | Greater than or equal to 1,000 |
| EPA action level for residential soil (U.S. EPA 1998) | 1,000 |
| EPA action levels for industrial soils (U.S. EPA 1998) | 5,000–20,000 |

**Note:** ATSDR - Agency for Toxic Substances and Disease Registry
EPA - U.S. Environmental Protection Agency
MTCA - Model Toxics Control Act
PCDD/F - polychlorinated dibenzo-*p*-dioxin and polychlorinated dibenzofuran
TEQ - toxicity equivalent based on data for 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

U.S. EPA (1998) outlines these levels in their 1998 Superfund directive as follows:

> One ppb (TEQs, or toxicity equivalents) is to be generally used as a starting point for setting cleanup levels for CERCLA removal sites and as a PRG for remedial sites for dioxin in surface soil involving a residential exposure scenario. For commercial / industrial exposure scenarios, a soil level within the range of 5 ppb to 20 ppb (TEQs) should generally be used as a starting point for setting cleanup levels at CERCLA removal sites and as a PRG for remedial sites for dioxin in surface soil. These levels are recommended unless extenuating site-specific circumstances warrant a different level.[4] (www.epa.gov/superfund/resources/remedy/pdf/92-00426-s.pdf)

EPA goes on to indicate that these levels are derived based on direct contact with soils, rather than bioaccumulation into the food chain. EPA indicates that, where states take the lead in cleanups, more stringent levels may be applied, but EPA indicates that this should only occur "where evidence exists that risks posed by the site differ from risks estimated using standard national default guidance values."

Thus, the EPA default cleanup levels are clearly intended to be applied in most cases. The guidance document identifies these values as both cleanup levels and preliminary remediation goals. The cleanup levels that would result from the draft rule amendment are much lower than dioxin cleanup levels as currently applied by EPA.

[4] One "ppb" is 1,000 ng/kg. "Dioxin" is PCDD/F expressed on a TEQ basis. A "PRG" is a preliminary remediation goal. "CERCLA" is the Comprehensive Environmental Response, Compensation and Liability Act, 42 U.S.C. § 9601 *et seq*.

A brief review of online abstracts of EPA records of decision for various sites in the western U.S. revealed several sites with a soil cleanup level of 1,000 ng/kg TEQ and a range from 6.7 to 1,000 ng/kg TEQ, and sediment cleanup levels ranging from 1,000 to 8,000 ng/kg TEQ within EPA Regions 9 and 10.

## Perspective from Background Concentrations

The Method B cleanup level that would result from the draft rule amendment (6.67 ng/kg) falls within background levels in developed areas and possibly even some rural residential areas and would thus be impractical to enforce (see Table 1). Background soil sampling for developed ("urban") areas in Washington state had TEQ concentrations that ranged from 0.13 to 19.5 ng/kg, assuming that undetected concentrations of congeners were zero (Attachment 2; Rogowski et al. 1999). If half the detection limit is used instead for undetected concentrations, as is the common practice in calculating the TEQ, this range increases to 0.64 to 21.9 ng/kg (Attachment 2). Use of the detection limit rather than half the detection limit would result in even higher TEQ concentrations (Attachment 2).

Background soil levels sampled in British Columbia indicated that TEQ concentrations ranged up to about 50 ng/kg (Van Oostdam and Ward 1995). A summary of studies on TEQ levels in soil in North America (NAS 2006; U.S. EPA 2003) reported an overall mean of 2.7 ng/kg and a range of study means of 0.11 to 5.7 ng/kg for rural soils. For developed ("urban") areas, a mean of 9.3 ng/kg with a range of survey means of 2 to 21 ng/kg was reported. These levels for soil were calculated assuming that undetected concentrations were zero and included only 11 of the 17 congeners. TEQ concentrations would be higher if half the detection limit was assumed for undetected concentrations and all 17 congeners were included.

These data indicate that if Ecology adopted a 6.67 ng/kg TEQ cleanup level, it is possible that a number of samples from developed areas in the state would have dioxin concentrations that exceed this level.

Although increases in TEQ concentrations resulting from inclusion of undetected congeners and changes in TEF methods are relatively small, these changes can result in exceeding the low cleanup level that would result by the draft rule amendment. This cleanup level is not far from the sum of half the analytical limits of detection of each of the 17 congeners. Thus, because the TEF concentrations of even undetected congeners are assumed to be present and added together, barely detectable dioxin concentrations could exceed the proposed Method B cleanup level. The NAS panel (see page 15; NAS 2006) stressed the importance of properly considering the influence of undetected congeners as well.

## Conclusions

Under the draft rule amendment, the MTCA cleanup level for TEQ mixtures of dioxin and furan congeners would be ten times lower than the current value. Scientific evidence, however, indicates considerable protectiveness in how risks and cleanup levels are developed for these compounds and does not support the necessity of a more stringent level for protection of human health. Nationwide cleanup levels considered health protective by EPA and ATSDR are orders of magnitude higher than the cleanup level that would result from the draft rule amendment. Moreover, the lower Method B cleanup level in the draft rule amendment is within background levels in populated areas of Washington, and near analytical detection limits. Therefore, this draft rule amendment is not necessary to protect public health and potentially will be impractical to implement.

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# Attachment 1

## Oral Bioaccessibility of Dioxins/Furans from Industrial Soils Using a Simulated Human G.I. Tract (Warmerdam et al. 2006)

# ORAL BIOACCESSIBILITY OF DIOXINS/FURANS FROM INDUSTRIAL SOILS USING A SIMULATED HUMAN G.I. TRACT

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**Introduction**

Polychlorinated dibenzo-*p*-dioxins and furans (PCDD/Fs) are common environmental contaminants with very high soil binding coefficients. Laboratory experiments with test animals indicate that the oral systemic absorption (bioavailability) of PCDD/Fs from soil is lower than for PCDD/Fs in lipophilic vehicles such as corn oil or other oil-based delivery media used in animal-feeding studies. For example, administration of tetrachlorodibenzo-*p*-dioxin (TCDD) in commonly used vehicles typically yields oral bioavailabilities ranging from 70%-90%[1-3], while the reported oral bioavailability of TCDD in soils ranges from 0.5-60% relative to reference oral formulations[4-8].

The relative bioavailability of soil-bound chemicals can be determined directly from feeding studies in which the concentration of the parent chemical or a metabolite is measured in tissues and/or via a "mass-balance" analysis involving measurements of chemicals excreted in the feces. However, there are anatomic and physiological differences between humans and common animal test species, which may confound the applicability of the results for human risk assessment purposes[9,10].

An *in vitro* bioaccessibility study permits derivation of a conservative estimate of the *in vivo* oral bioavailability of soil-bound chemicals in humans that can be used as an alternative or supplement to animal studies. In a bioaccessibility study, the soil is extracted with fluids that simulate the stomach and small intestine segments of the human GI tract. The amount of chemical present in the liquid phase following the extraction is used to determine the bioaccessible fraction. Because the extraction conditions are believed to be at least as harsh as those present *in vivo*, presumption of 100% absorption of the bioaccessible fraction yields a conservative estimate of bioavailability. The *in vitro* approach avoids animal use, has the advantages of simplicity and lower cost, and permits evaluation of many different variables (effect of soil type, soil particle size, chemical concentration, etc.) that simply is not practical with the more costly and time-consuming *in vivo* studies.

To date, there are no published bioccessibility measurements of PCDD/Fs in industrial soils. In this paper, we describe the bioaccessibility results for PCDD/Fs in soils near an operating facility in the U.S. The measured TEQ in the soils ranges from 0.7 µg/kg to 23.6 µg/kg and OCDF is the primary congener, comprising approximately 90% of the total PCDD/F mass. The purpose of this study is to supplement the existing bioaccessibility and bioavailability data for PCDD/Fs in contaminated media.

**Materials and Methods**

A total of eight surface soil samples (0-3 inches depth) were collected from an industrial site with historical PCDD/F discharges. The soils were analyzed for 17 polychlorinated dibenzo-*p*-dioxins and furans with EPA method SW 8290 using high resolution gas chromatography / high resolution mass spectrometry.

The soil samples were air dried and sieved in an attempt to isolate the fraction less than 250 microns in diameter. Two samples (#4 and #5) were coarse grained and could only be sieved to a < 500 micron fraction. One sample (#3) was coarse grained and gummy and was used unsieved.

The sieved fraction of each sample was subjected to the following *in vitro* extraction method:

The extractions were conducted in 1-liter Teflon bottles, which were immersed in a water bath at 37° C. Mixing was accomplished with a stir table oscillating at 30 revolutions per minute. A buffered solution was prepared by adding 60 grams of glycine (0.2 M; Sigma UltraPure®) to 4 L of Type II deionized (DI) water, and adjust to pH 1.5 with concentrated HCl (~240 mL). To this, 32.5 g of sodium chloride (NaCl, concentration of 150 mM in stomach fluid), 4.00 g of pepsin (activity of 800-2,500 units/mg, final concentration of 1.00 g/L in stomach fluid), 20 g bovine serum albumin (minimum 98 percent, final concentration of 5 g/L in stomach fluid), and 10 g mucine (Type III, purified from porcine stomach; final concentration of 2.5 g/L in stomach fluid) were added. Eight hundred mL of the gastric solution were placed in each Teflon bottle, and 4.8 mL of oleic acid (90%; Aldrich Chemical) were added. Eight grams of test soil were added, and the resulting mixture was stirred at 30 rpm on the mixing table for one hour.

After the 1-hour simulated gastric portion of the test, the solution in each bottle was adjusted to pH 7.2 using sodium hydroxide (50 percent w/w, approximately 10 mL). Finally, 480 mg pancreatin (activity equivalent to 8 × U.S.P. specifications) and 3.2 mg bovine bile (50 percent bile acids, mixture of free and conjugated acids) were added to each reaction vessel and stirred at 30 rpm for 4 hours to simulate small intestinal-phase extraction.

Each reaction vessel was centrifuged at 5000 ×*g* for 10 minutes. The supernatant was decanted into a graduated cylinder and total volume was measured. All eight samples were analyzed for 17 PCDD/F congeners at Alta Analytical Laboratories, Inc. (Alta) in El Dorado Hills, CA. Quality assurance samples included an extraction blank, a spiked extraction blank, and a triplicate analysis of one sample (#2) to assess reproducibility.

**Results and Discussion**

A majority of the soil TEQ concentration and extractant resulted from four congeners: 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6,7,8-HxCDF, and 1,2,3,4,6,7,8-HpCDF. As shown in Figure 1, the average % congener contribution to total TEQ was very similar for soils vs. extractants.

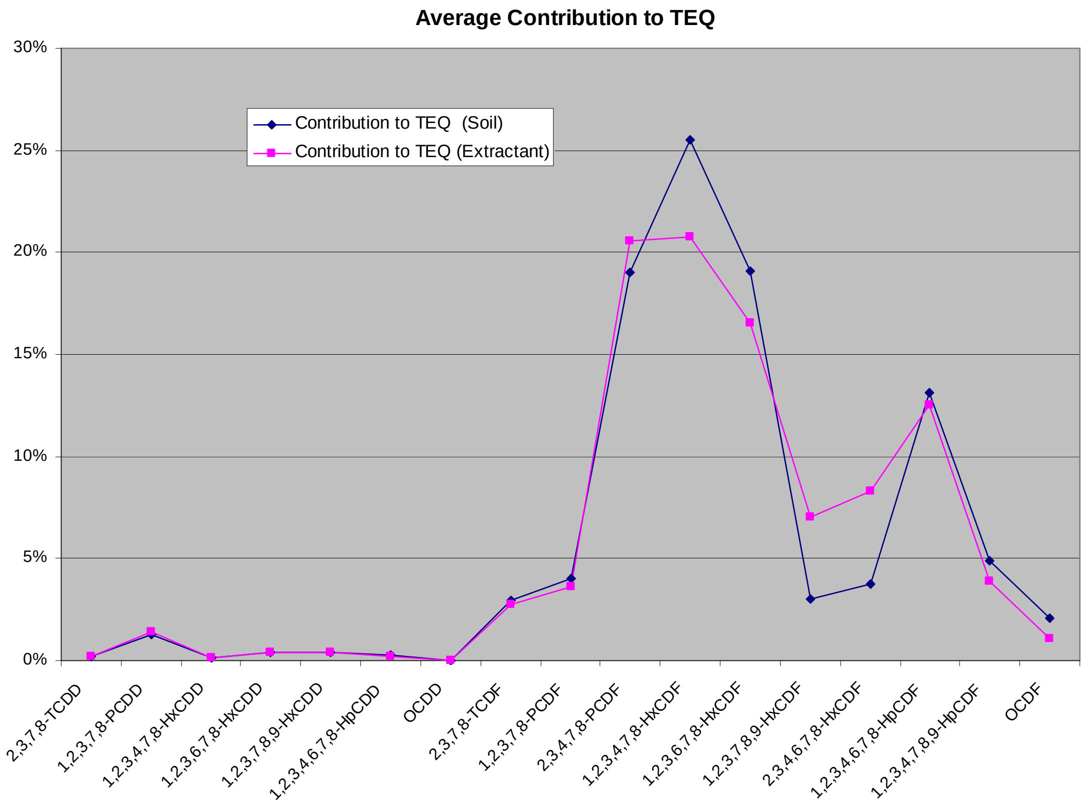


Figure 1 – Average contribution to TEQ (Soil and Extractant)

Bioaccessibility total TEQ results for the eight samples ranged from 9 to 46%, with an overall average of 22%. There did not appear to be any trends with respect to degree of bioaccessibility vs. initial soil concentration. The bioaccessibility values for TCDD ranged from 2 to 75%, (average of 24%). Bioaccessibility was lowest in samples #3, #4, and #5; these samples were either sieved to below the 500-micron particle-size level, rather than the 250-micron level (#4 and #5), or not seived at all (#3). This result suggests that, at least with the soils used in this study, bioaccessibility may decrease with increasing particle size. As indicated in Figure 2, the bioaccessibility of the two congeners 1,2,3,7,8,9-HxCDF and 1,2,3,4,6,7,8-HxCDF was clearly elevated relative to the other congeners

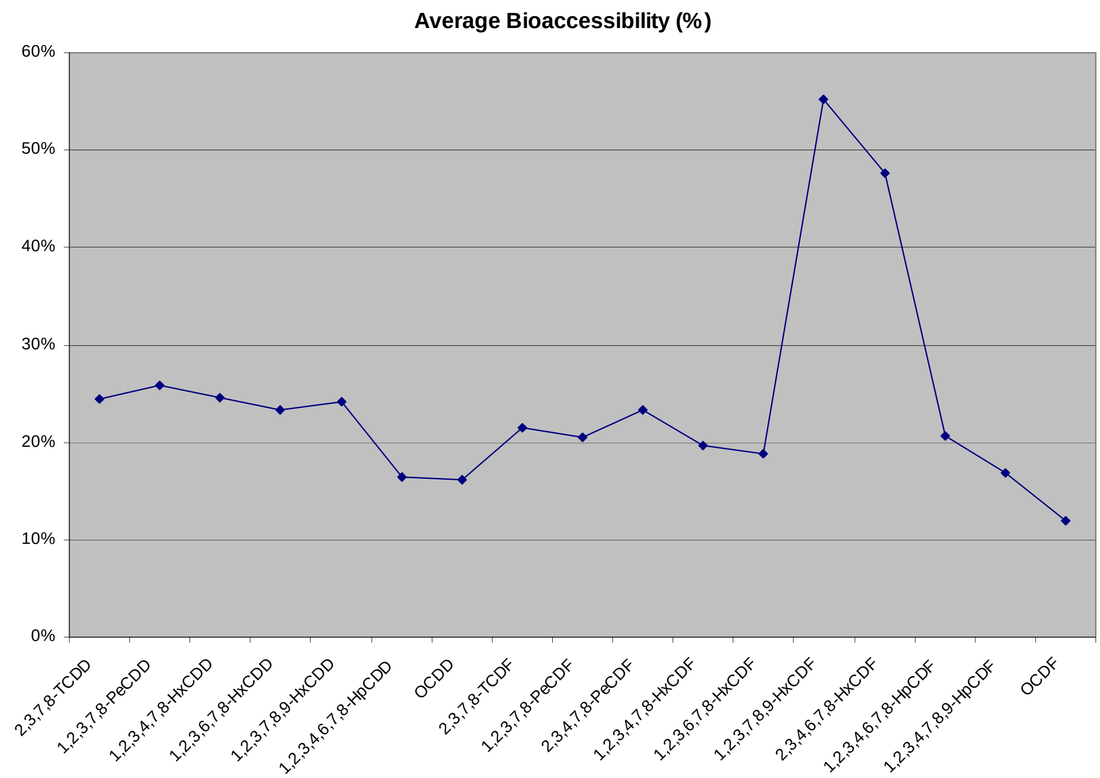


Figure 2 – Average Bioaccessibility of 17 PCDD/F congeners

The mean bioaccessibility measured in this study (22%) is within the range determined from *in vivo* TCDD bioavailability studies (0.5%-60%). This value agrees with values from other, similar studies and likely represents an upper bound estimate of oral bioavailability for these soils[1,11].

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## Attachment 2

## TEQ Values of Soil Samples Collected from Selected Washington State Land Use Areas (Rogowski et al. 1999)

## Appendix 3-G. TEQ values of soil samples collected from selected Washington State land use areas (ng/kg)

| Land Use | TEQ ND = 0 | TEQ ND = 1/2 DL | TEQ ND = DL | Lab # |
|---|---|---|---|---|
| **Forested Lands** | | | | |
| East non-commercial | 5.16 | 5.57 | 6.04 | 328341 |
| East non-commercial | 0.449 | 1.60 | 2.76 | 338331 |
| West non-commercial | 4.93 | 5.69 | 6.46 | 308000 |
| West non-commercial | 2.57 | 4.86 | 7.15 | 318241 |
| East commercial | 0.0330 | 1.05 | 2.06 | 338330 |
| East commercial | 0.914 | 3.84 | 6.76 | 318243 |
| West commercial | 2.02 | 2.70 | 3.38 | 328332 |
| West commercial | 2.42 | 2.80 | 3.17 | 338333 |
| **Open Areas** | | | | |
| East rangeland grazed | 0.0431 | 0.891 | 1.74 | 338332 |
| East rangeland grazed | 0.0400 | 1.31 | 2.59 | 328336 |
| West rangeland grazed | 0.617 | 1.40 | 2.19 | 308004 |
| West rangeland grazed | 4.59 | 5.87 | 7.15 | 328331 |
| East non-grazed | 0.0460 | 0.631 | 1.22 | 328335 |
| East non-grazed | 0.0834 | 1.36 | 2.64 | 328340 |
| West non-grazed | 2.37 | 2.87 | 3.37 | 328330 |
| West non-grazed | 0.330 | 1.09 | 1.84 | 318242 |
| **Urban Areas** | | | | |
| Richland | 4.75 | 7.09 | 9.44 | 328337 |
| Kennewick | 1.08 | 1.92 | 2.76 | 328339 |
| Spokane | 0.984 | 3.00 | 5.01 | 328333 |
| Tacoma 1 | 19.5 | 21.9 | 24.4 | 318239 |
| Tacoma 2 | 9.47 | 11.7 | 13.9 | 318240 |
| Seattle 1 | 0.313 | 0.699 | 1.08 | 318230 |
| Seattle 2 | 5.13 | 5.47 | 5.81 | 318238 |
| Seattle 3 | 4.72 | 5.78 | 6.84 | 318236 |
| Seattle 4 | 0.133 | 0.639 | 1.14 | 318231 |
| Seattle 5 | 0.804 | 1.21 | 1.62 | 318235 |
| Seattle 6 | 2.10 | 3.02 | 3.94 | 318232 |
| Seattle 7 | 0.729 | 1.52 | 2.30 | 318233 |
| Seattle 8 | 5.96 | 6.31 | 6.66 | 318234 |
| Seattle 9 | 1.36 | 2.81 | 4.26 | 318237 |
| **Duplicate Samples** | | | | |
| Spokane | 0.326 | 4.36 | 8.39 | 328334 |
| Richland | 4.50 | 8.26 | 12.0 | 328338 |

ND = Non-detect
DL = Detection limit
ND = 0: if congener not detected, concentration assumed = 0
ND = ½ DL: if congener not detected, concentration assumed = ½ detection limit
ND = DL: if congener not detected, concentration assumed = detection limit